

Breath Cooling System and CO Removal for Wildland Firefighters

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TDA
Research

Abstract

Each year, an estimated 80,000 firefighters battle wildfires, often spending long hours at the fire front where they are exposed to high levels of smoke and heat. Sudden changes in weather or fire conditions increase the chances of being trapped by an uncontrolled wildfire or caught in a burnover. Such situations drastically increase the danger posed to the firefighter. Wildfire smoke contains a large number of toxic components, pulmonary irritants (particulates), and high concentrations of carbon monoxide (CO). In wildfires, many firefighters are injured or killed by heat damage to their airways or lungs when they breathe superheated air, and this risk is actually greater than that of external burns.

Currently, there is no suitable respirator available to protect firefighters from exposure to CO or superheated air. As a result, TDA Research, Inc. (TDA) is developing a small, cartridge-type device that we call the Wildfire Rescue Respirator, or WFRR, that can be easily worn by firefighters to cool superheated air to safe levels for breathing in the event that the firefighter becomes trapped by a wildfire. The WFRR would be used in inside a fire shelter during a burnover to provide the user with a source of cool air should the shelter become compromised. TDA's device also incorporates a CO oxidation catalyst that destroys CO at temperatures between ambient and 350°F by oxidizing CO to non-toxic carbon dioxide (CO₂), thus protecting the firefighter.

Introduction

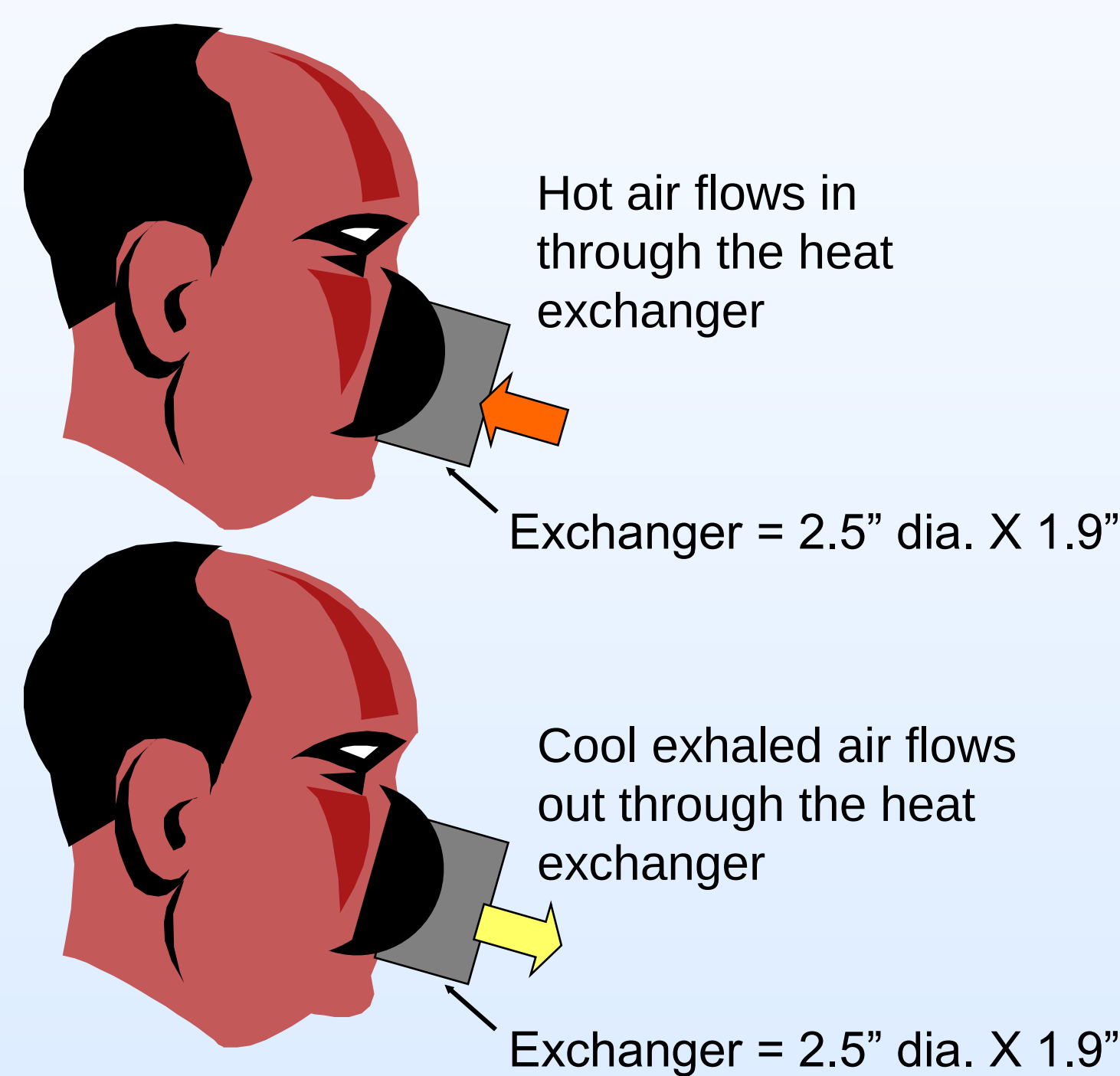
The most common wildfire hazards encountered on a day-to-day basis are smoke inhalation and burnovers. During a burnover, the firefighter is trapped by advancing flames, and in addition to the thermal hazard, the smoke contains a large number of hazardous components, including pulmonary irritants (particulates) and toxic compounds generated during combustion such as formaldehyde, acetaldehyde, sulfur dioxide and carbon monoxide. Should a firefighter become trapped in a burnover, skin burns are of secondary importance compared to protecting the airways and lungs from exposure to superheated air and toxic gases (especially carbon monoxide, CO). Currently, only a self-contained breathing apparatus (SCBA), can protect against all contaminants (including CO) and superheated air, but SCBA are much too heavy (30-50 lb), cumbersome, and don't last long enough for the wildland firefighter. More firefighters are injured or killed from heat-damaged airways or lungs caused by breathing superheated air, than by external burns. For example, during a test burn in Montana where vehicles, fire shelters and other equipment were instrumented with recording thermocouples, temperatures spikes as high as 284°F were observed inside the fire shelters. In a similar test burn in the Los Angeles area, 320°F temperature spikes were observed.

Wildland firefighters are exposed to concentrations of CO that are in excess of OSHA ceiling/excursion limits during as much as 25% of their time spent fighting fires and CO blood concentrations can increase to 150 times normal levels in 1 minute. At lower concentrations (ca. 21 ppm) CO poisoning produces difficulty with thinking, performing complex tasks, and causes dizziness, all of which increase the risk of a fatality in a burnover when fast, clear thinking is at a premium. Therefore, a small portable device that protects the firefighter from superheated air and CO poisoning will increase their chances of surviving a burnover.

To date there have been no wildland firefighter respirator standards, however, there is currently one being drafted by the National Fire Protection Agency (NFPA). The goal of the standard (NFPA 1984) will be to specify the "minimum design, performance, testing, and certification requirements for respirators to provide protection from inhalation hazards for personnel conducting wildland fire fighting operations."

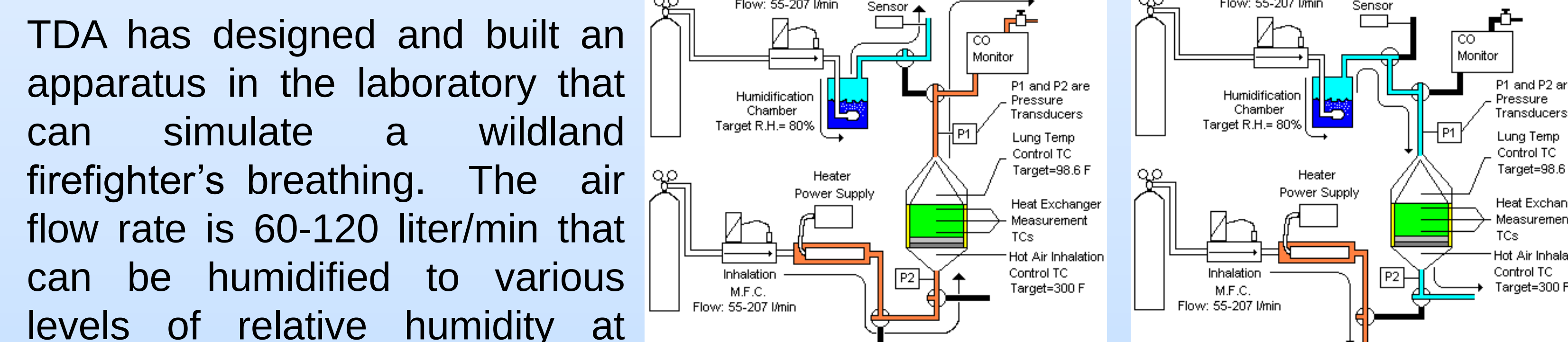
Methods

TDA Research, Inc. is developing a proprietary heat exchanger and catalyst that will cool a wildland firefighter's breath and remove CO from the environment. A combination of numerical modeling and materials testing have been employed to design and test various heat exchanger materials. In addition, our expertise in CO oxidation catalyst development has been used to design and test catalysts that are effective for oxidizing CO to CO₂ at both low-to-moderate (32 - 77 F) and high temperatures (248°F).

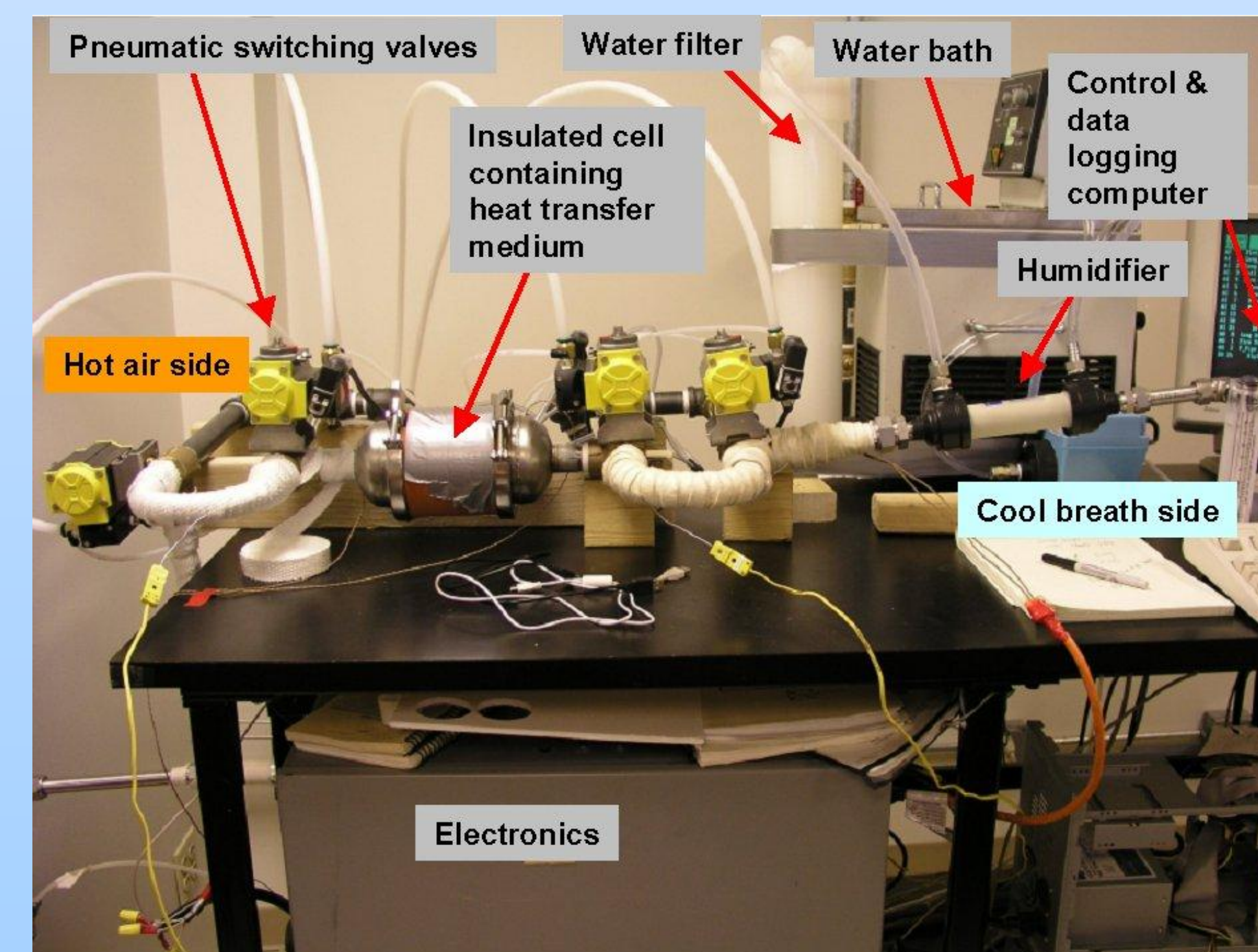


Design Parameters

- Metabolic rate = 1,000 Btu/h
- Altitude = sea level to 10,000 ft
- Ambient dew point = < 90°F
- Allowable pressure drop < 2 inch water
- Inlet air temperature = 250-350°F
- Air temperature into nose < 100°F
- Air flow = 60-120 liter/min



Schematic of test apparatus.



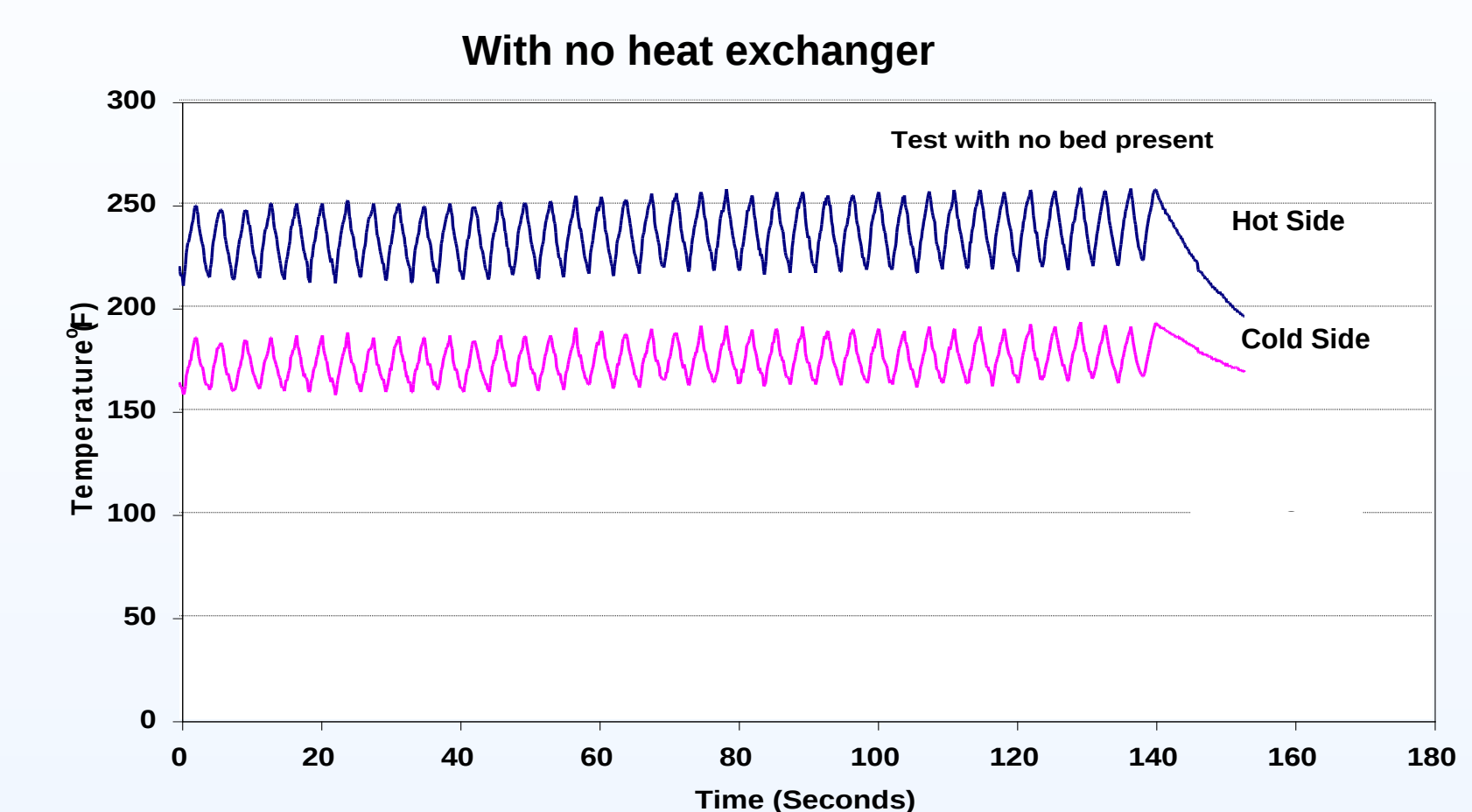
Photograph of test apparatus.

Author Contact Information:

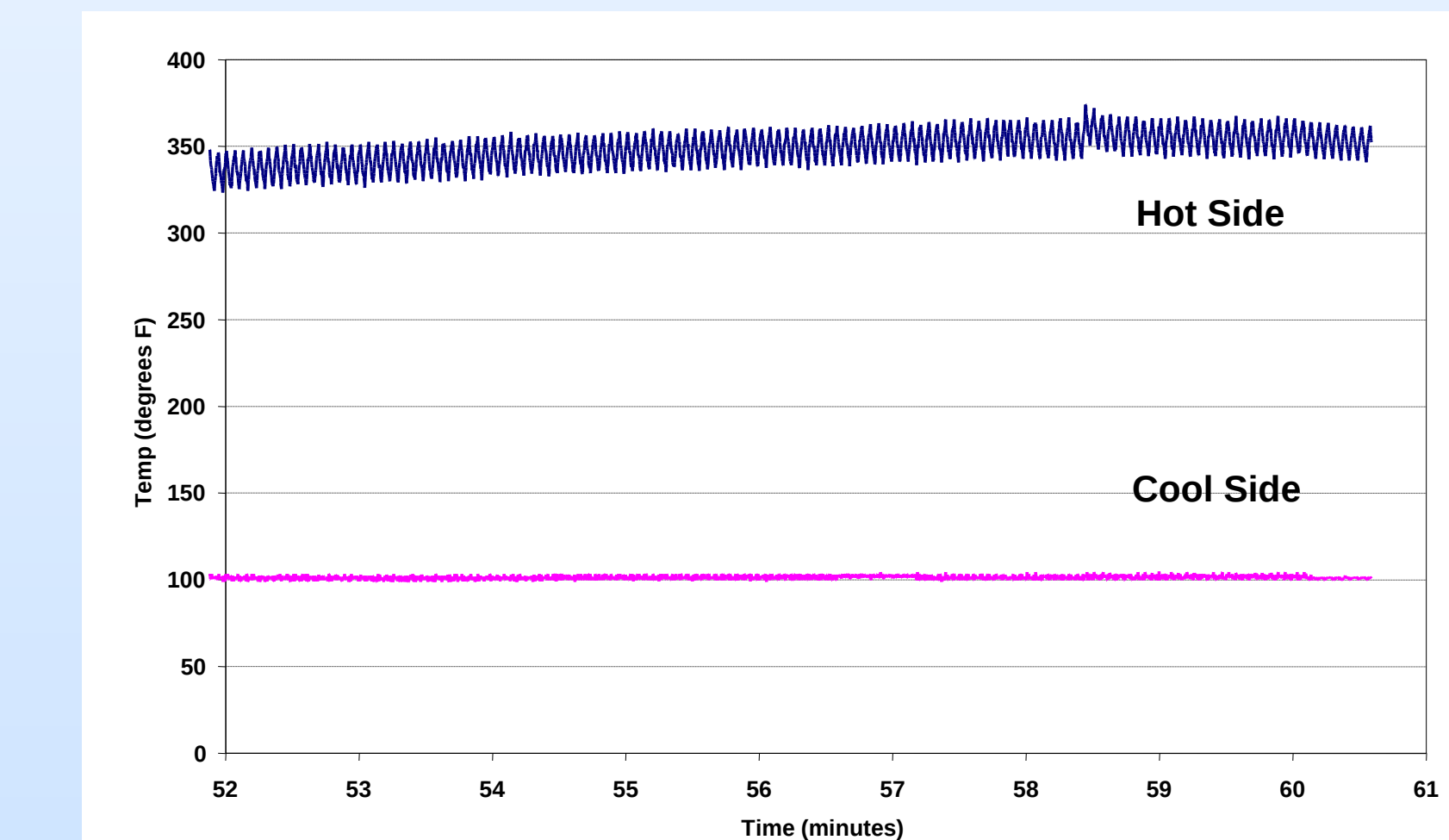
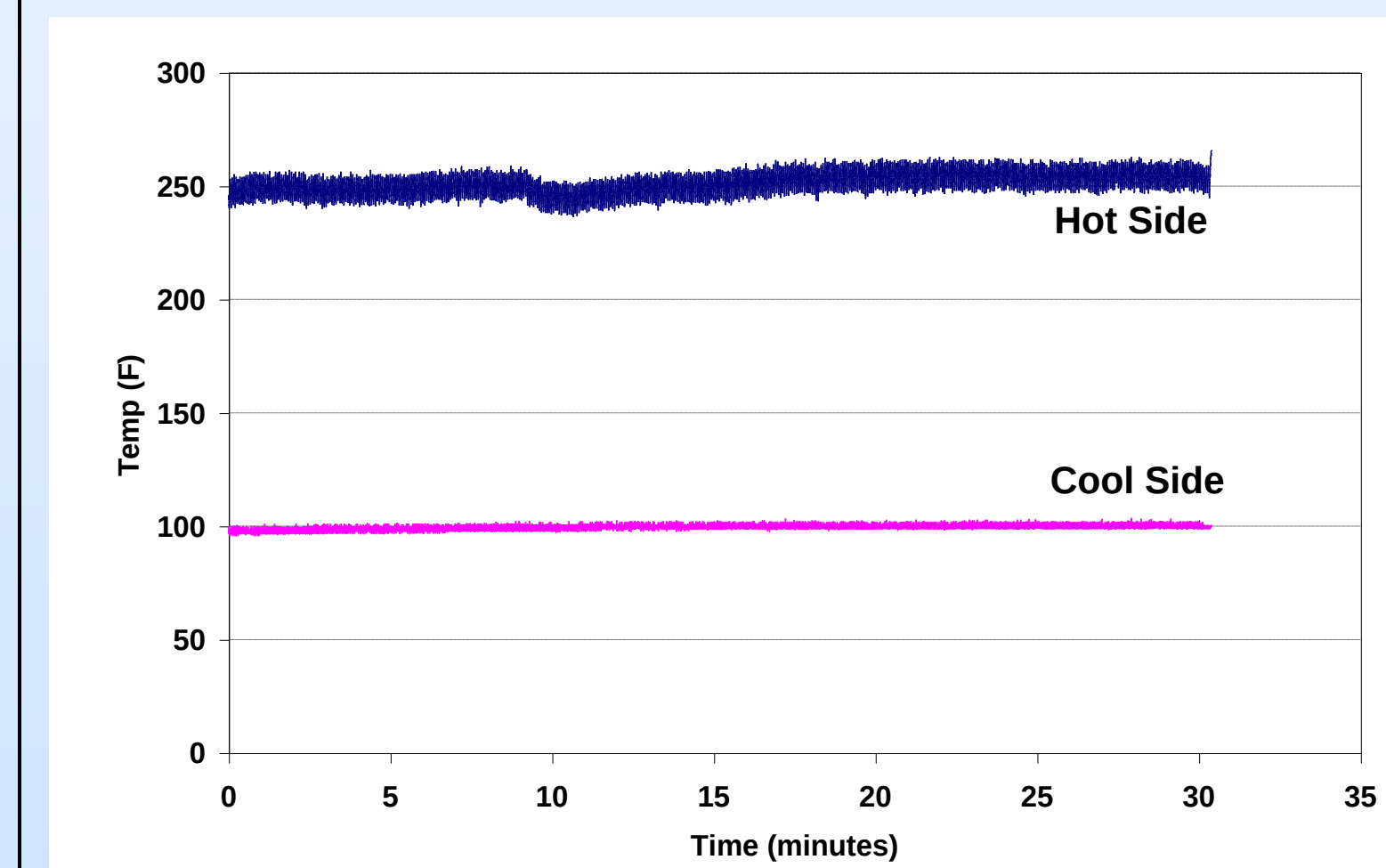
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Results

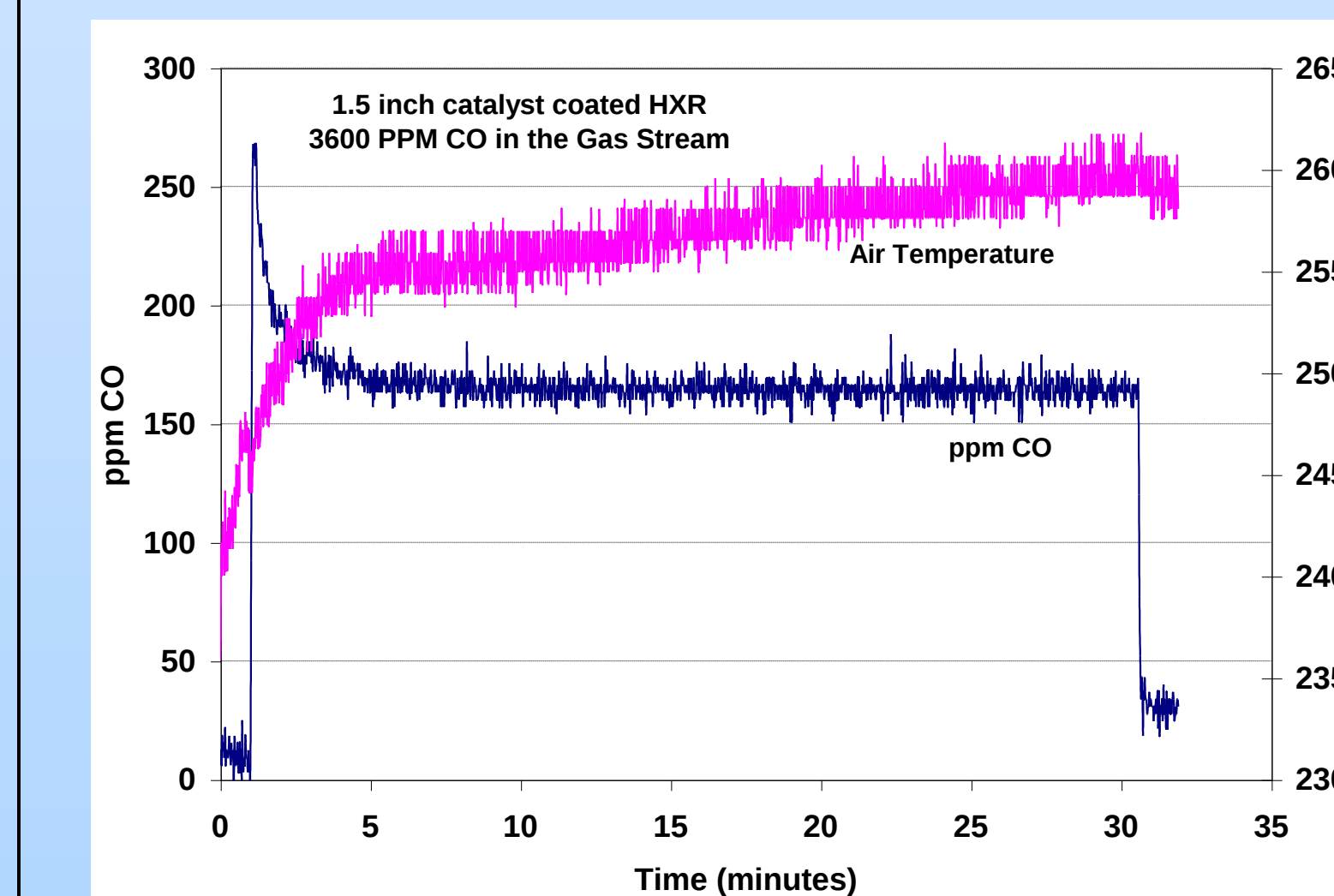
TDA ran a blank test (no heat exchanger in the test cell) to verify the performance of our heat exchanger. The temperature on the "cold side" of the test cell (metal canister) reached 190 F within 2 minutes when the "hot air" temperature was 250°F. With the heat exchanger in place, the temperature was reduced to ~98°F from hot air side temperatures as high as 350°F within seconds.



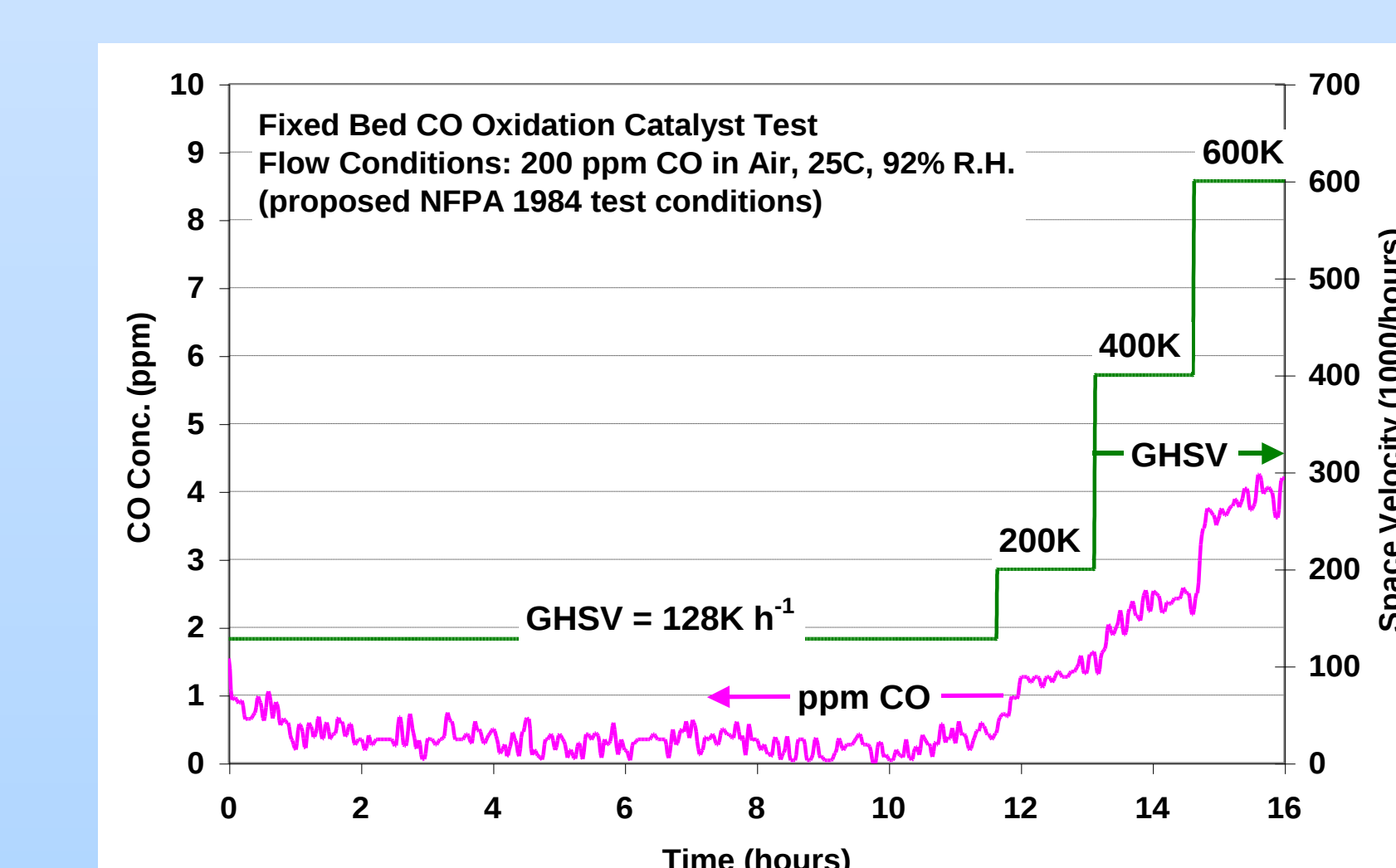
TDA has tested its oxidation catalyst with CO contaminated air at ambient temperature and at 260 F where the catalyst was coated onto the surface of the heat exchanger to meet the CO removal requirements that have been drafted in NFPA 1984. In both cases, the catalyst reduced the CO concentration by more than 90%.



Results with 250°F air on "Hot Side"



Results with 350°F air on "Hot Side"



CO removal with catalyst coated HXR

Removal of 200 ppm of CO at 25 C and 92% relative humidity

Conclusions

With funding from the NIOSH SBIR program, TDA is developing a heat exchanger that can reduce the temperature of a wildland firefighter's breath from 350°F to 98°F in seconds. In addition, we are developing CO oxidation catalysts for CO removal at ambient and higher temperatures that will meet the new NFPA 1984 standards.

Disclaimer

The findings and conclusions in this presentation have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.